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MEMORIA
Sociedad de Ciencias Naturales La Salle
Tomo XLVIII. Suplemento nº 3, 1988

COMMERCIAL CATCH LENGTH-FREQUENCY DATA AS A TOOL FOR FISHERIES MANAGEMENT WITH AN APPLICATION TO THE PUERTO RICO TRAP FISHERY

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SUMMARY

Length-frequency data derived from sampling commercial fisheries catch can be used to estimate growth parameters of various species in the catch. These growth parameters then can be used in a yield-per-recruit type fisheries model to make preliminary management recommendations on the amount of fishing effort and size of fish at first capture necessary to maximize yield in a fishery. Length-frequency data collected from the Puerto Rican commercial fisheries were used to estimate growth parameters with the ELEFAN method. Three closely related species of grunts (*Haemulon* sp.) which comprise the second largest catch by weight in the Puerto Rico demersal trap fishery are compared. A yield-per-recruit analysis was performed on each species to compare possible management strategies. The three species of grunts grew differently and had different mortality rates, but the yield-per-recruit analyses suggests similar management strategies to maximize yield for each species.

RESUMEN

Los datos de distribución de talla obtenidos de muestras de capturas en pesquerías comerciales pueden ser usados para estimar parámetros de crecimiento de las diversas especies capturadas.

Estos parámetros de crecimiento podrían ser usados en modelos pesqueros de rendimiento por recluta "yield-per-recruit" para preparar reco-

mendaciones preliminares de manejo sobre la cantidad de esfuerzo pesquero y el tamaño del pez capturado por primera vez; factores necesarios para obtener el máximo rendimiento en la pesquería. Los datos de distribución de talla recolectados de las pesquerías comerciales de Puerto Rico, fueron usados para estimar parámetros de crecimiento usando el método de ELEFAN.

Se compararon tres especies de la familia Haemulidae (*Haemulon* sp.). Estas especies ocupan el segundo renglón en descarga por peso, en la pesquería de trampas (nasas) en Puerto Rico. Se hizo un análisis de rendimiento por recluta para cada una de las especies comparando posibles estrategias de manejo. Las tres especies analizadas presentaron tasas de crecimiento y mortalidad diferentes; sin embargo, el análisis de rendimiento por recluta sugiere la utilización de estrategias similares de manejo, si se pretende obtener un rendimiento máximo para cada especie.

INTRODUCTION

There are two modelling approaches used in studying fish populations and assessing the state of fish stocks. One, production models deal with biomass, catch, and fishing effort. Production models determine the maximum sustainable or optimal yield for a given fishery and assess the appropiate fishing effort to attain this yield. This type of model requires a long series (ten's of years) of good catch and effort data along with data from the early exploitation phase of the fishery. Once a fishery is being fully exploite it may be too late for the application of a production model. Also accurate total catch and effort data have been notoriously hard to collect in most fisheries.

An alternative group of models are the yield-per-recruit type. This set of models use information on the population, such as growth parameters and mortality rates, to estimate the maximum yield per individual in the population based on fishing mortality and size at first.capture (Gulland, 1983). Optimal levels of fishing mortality and fish size can be determined to give the best yield. These models have the advantage of giving immediate results on the state of the fishery. They do not require information on catch and effort, but do require relatively extensive biological information on each species. This could be a daunting task in the multispecies context of a tropical fishery. More detailed information on these models can be found in Gulland (1983).

Munro (198b) proposed a data acquisition system for the assessment of tropical multispecies fisheries with an emphasis on the collection of length-frequency data rather than catch/effort data. He does not suggest the abandonment of the collection of catch/effort data but rather the focusing of limited fishery management resources into an area of immediate (as well as long term) results. The question raised at this point is can length-frequency data adequately estimate population growth parameters and mortality rates. Recently many advances have been made in the area of lenght-frequency data analysis (Pauly, 1982; Caddy, 1986).

Munro advises using data obtained from scientific surveys by fisheries personnel rather than commercial catch. This proposal may involve greater effort and resources than originally necessary for acquiring catch/effort data. Due to limited fisheries budgets commercial catch data (fisheries-dependent) may be the only cost effective method available to assess fish stocks on a regular basis. Fisheries-dependent data can be highly biased due to nonrandom sampling of the catch and usually does not reflect the true population structure due to fishing gear selectivity. The sampling of the commercial catch necessitates constant monitoring to provide a relatively unbiased estimator of the population but does not require an enormous effort. That is to say more measurements does not necessarily make for a better estimate but that sampling of the catch must effectively cover all areas and types of fishing including seasonal and lunar variability. Scientific surveys could be used to validate the sampling procedure of the commercial catch.

In Puerto Rico the marine fisheries laboratory, presently under the auspices of CODREMAR (Corporation for the Development and Administration of the Marine, Lacustrine, and Fluvial Resources of Puerto Rico), has implemented a port agent sampling survey of length-frequency data on selected reef fish for several years that has generated a large amount of data. Due to concerns about the reliability of this data for stock assessment little analysis has been forthcoming.

Species of the genus *Haemulon* (Haemulidae), known as grunts, boquicolorado, or roncos, are an important component of the Puerto Rico demersal fishery ranking second by weight and third by value (García-Moliner, 1986) and are regulated in federal waters under the fishery management plan for the shallow-water reef fish fishery of Puerto Rico and the U.S. Virgin Islands by the Caribbean Fishery Management Council (CFMC, 1985). In this paper I undertake an analysis of length-frequency data from the Puerto Rico commercial catch on *Haemulon* sp. to assess the state of the fishery and allow preliminary management strategies to be developed for this important group of fishes.

METHODS

The Beverton and Holt yield-per-recruit model requires estimates of growth parameters (specifically of the von Bertalanffy type) and mortality rates, particularly fishing mortality (F), natural mortality (M), and total mortality (Z).

I will deal exclusively with the von Bertalanffy growth function (VBGF), which has two important parameters in fisheries science, L_{oo} and K, that are used by many present stock assessment models including the yield-per-recruit model (Ricker 1975). The equation can be written as:

$$l_t = L_\infty[1 - e^{-K(t-t_o)}]$$

where:

l_t = length at time
L_∞ = asymptotic length
K = growth coefficient
t = time
t_o = time at age zero

For the present analysis t_o is not important, thus it is set to zero.

Beverton and Holt (1964) developed a length based version of their yield-per-recruit model that needs relatively few input parameters. Gulland (1983) gives the formulation of this equation as:

$$Y'/R = E\,(1 - C)^{MK^{\prime}} \sum_{n=0}^{3} \frac{Un\,(1 - C)}{1 + \frac{(n)\,(K)}{M}\,(1 - E)}$$

where:

Y'/R = relative yield per recruit (independent of units).
$E\ (= F/Z)$ = exploitation rate, (a measure fishing intensity).
$C\ (= l_c/L_\infty)$ = relative size at first capture.
l_c = length at first capture.
L_∞ = asymptotic length of VBGF.
K = growth coefficient of VBGF.
M = instantaneous natural mortality.
F = instantaneous fishing mortality.
$Z\ (= M + F)$ = instantaneous total mortality.

when: $n = 0, 1, 2, 3$
$U_n = 1, -3, 3, -1$, respectively.

This type of yield-per-recruit analysis assumes:

1) recruitment is relatively independent of stock size.
2) constant fishing mortality over fishable lifespan.
3) knife-edge recruitment and selection.
4) isometric von Bertalanffy growth, and
5) mortality expressed by a negative exponential curve.

A more extensive version of this model has been used to develop management strategies for warm temperate reef fishes in the southeastern United States including some grunt species (Huntsman *et al.*, 1983).

Growth Parameter Estimation

Three courses can be taken in estimating growth parameters: aging by growth marks on hard parts, tagging experiments, and length-frequency analysis.

Aging by growth marks has a long history and is commonplace today for most commercial species in boreal and temperate water (Ricker 1975). In these regions winter minima in water temperature imposes a period of growth cessation which, in turn, causes definitive marks on hard parts such as scales, otoliths, vertebrae, and other bones. Unfortunately temperature fluctuations in the tropics are rarely great enough to significantly affect growth rates (Pauly and Ingles, 1981; Appeldoorn, 1987). Other processes have been implicated in growth mark formation such as spawning or food availability (Reshetnikov and Claro, 1976). Although these processes have been shown to cause growth checks in temperate water fishes their occurrence in tropical fishes must be verified and validated as to an annual nature because some species may spawn year-round and food availability may be quite variable.

Examination of scales and otoliths from tropical populations of white grunts in Jamaica (Gaut and Munro, 1983) and Puerto Rico (pers. obs.) reveal no obvious annual periodicity. In fact Munro (1983a) found only one species that he examined from Jamaica to be suitable for aging by growth marks. Yet a recent study of yellowtail snapper *(Ocyurus chrysurus)* from the Virgin Islands and Puerto Rico suggest that growth marks are present and annual in nature on some tropical fish (Manooch and Drennon, 1987).

Aging methods have improved in the area of daily growth marks, which can now be used to estimate growth rates at different lengths thus fitting a VBGF to estimate growth parameters (Ralston and Miyamoto, 1982). Both annual and daily growth mark analyses are laborious and subject to error based on skill of the readers. It is probably not conceivable that all species (or even important species) in tropical commercial catches could be aged without a major expediture for age analysis alone. Also there is no guarantee that the growth equation will be constant as fishing effort changes. Limited amounts of ageing can be used in conjunction with length-frequency data to improve growth function fitting (Morgan, 1985).

Tagging studies have also been used to determine the growth equation of some fish populations (Munro, 1982). Tagging results must cover a range of sizes (and ages) to adequately fit the VBGF. The tagging process and tags can adversely affect growth (Randall 1962, 1963). Low number of tag returns, cost, and variable, if not erroneous, growth rates derived from tagging does not suggest it as a primary method of estimating growth parameters in reef fish.

Length-frequency data has been used since the late 1800's to estimate growth rates (Ricker, 1975). This analysis follows the progression of modes in length-frequency data through time or within a sample to estimate growth rates. Munro (1983a) originally analyzed growth rates of many reef-fish species in Jamaica with the modal progression technique. The method of selecting and determining modes as year classes has been improved in recent years by introducing computer fitting of normal distributions to succesive year classes (Hasselbald, 1966). This has culminated with recent computer programs, which require input of estimated positions of year classes and their variances (Yong and Skillman, 1975; MacDonald and Pitcher, 1979). The fishery scientist must subjectively choose the positions of year classes then test to see if modes selected are actually different year classes. In many instances only one mode will be present in a sample with older year classes obscured by overlap in length.

Pauly and David (1981) have proposed a more objective method of estimating growth parameters embodied in a set of programs called ELEFAN (Electronic Length Frequency Analysis). These programs fit various combinations of L_∞ and K (VBGF parameters) to smoothed length-frequency samples to find the best fit combination(s) of parameters. I used the October 1986 update, compiled Kiel version of ELEFAN for the IBM microcomputer (Brey and Pauly, 1986) to estimate growth parameters for the three dominant species of grunts in Puerto Rico, *Haemulon flavolineatum*, (French grunt), *H. plumieri* (white grunt), and *H. sciurus* (bluestriped grunt). Data were collected from fishing ports around Puerto Rico by the biostatistical sampling program of the Commercial Fisheries Laboratory, CODREMAR. Fish were measured to the nearest millimeter fork length (FL). The catch analyzed represented fish caught by arrowhead type fish traps (nasas) covered with galvanized hexagonal mesh (4.2 cm maximum aperature). Over 80% of the grunts were taken by this gear type. I summarized length data by month for 1984 and 1985 into one centimeter size classes (e.g., 20 = 20.0-20.9 cm). As ELEFAN analysis is sensitive to samples with low number of individuals I selected only months with more than 40 individuals for bluestriped grunts, 90 individuals for French grunts, and 150 individuals for white grunts based on overall sample size. These subsets of months were used for initial VBGF parameter in ELEFAN. Due to small annual temperature range in Puerto Rico and to simplify computations the seasonal growth oscillation constant (C) was set to zero. The resultant curve (the product of recruitment to the fishery and gear selection), obtained from catch curve analysis (see below), was used to adjust the original samples for selection (Pauly, 1986). Growth parameters were re-estimated and the selection corrected results were used as the best fit VBGF parameters.

Data for 1974 were obtained from Stevenson (1976). Three samples, September-October 1973, June 1974, and October 1974 were use in ELEFAN to obtain VBGF parameters. Only 1974 data were used to estimate mortality and the state of the fishery. These data are relatively fishery independent, as Stevenson used local fishermen and traps to collect data. Also data was collected only from the southwestern coast of Puerto Rico.

Mortality Estimates.

Three methods were used to estimate total mortality (Z): length-converted catch curve (Pauly, 1983), Beverton and Holt's (1956) equation, and Hoening, *et al.*, (1983) equation. All length measurements were used in mortality estimation summarized over each year. A length-converted catch curve was obtained from the ELEFAN 2A program to estimate total mortality (Pauly 1983).

Beverton and Holt's (1956) equation:

$$Z = \frac{K\,(L_\infty - \bar{l})}{(\bar{l} - l_c')}$$

where:

$\bar{l}$ = mean length of fish greater than l_c'.

l_c' = initial length of the first fully recruited size class, in this case the first class to the right of the modal size class.

was used to estimate Z, as well as the method of Hoening *et al.* (1983) based on modal length:

$$Z = \frac{K\ (\log_e 2)}{Y_m - Y_c}$$

where:

$Y_m = -\log_e(1 - l_m/L_\infty)$

$Y_c = -\log_e(1 - l_c/L_\infty)$

l_m = modal length of fish greater than l_c.

Natural mortality (M) was estimated from Pauly's (1980) equation as a function of L_∞ K, and mean annual water temperature at Puerto Rico. Fishing mortality (F) was simply determined from F = Z - M.

Mean length at first capture (l_c) was estimated from the selection curve of the length-converted catch curve in ELEFAN 2A program using Gulland's formula (Gulland, 1983; Pauly 1984).

Management Strategy

Based on the findings of Beddington and Cooke (1983) fishing at a level of F_{max} or its equivalent in this analysis E_{max} may lead to recruitment overfishing or may be at an unrealistically high fishing effort. A level of $F_{0.1}$ (or $E_{0.1}$) has been suggested as a better management strategy (Gulland and Boerema, 1973; Deriso, 1987). $F_{0.1}$ is the level of F for which the marginal increase in yield per recruit is 10% of its value at F =0 (Gulland and Boerema, 1973). Deriso (1987) established the relationship between $F_{0.1}$ and maximum sustainable yield and found the $F_{0.1}$ criterion to be a constant harvest rate policy. Many stocks in northern waters are presently managed at this level of fishing (Doubleday *et at.*, 1984) and I use $E_{0.1}$ as the optimum level of exploitation to manage the fish stocks analyzed herein.

The present state of the fishery was determined by the yield-per-recruit parameters, C. and E. $E_{0.1}$ was determined from the program of Pauly and Soriano (1986).

Deviations from the knife-edge recruitment assumption can significantly affect results of the yield-per-recruit analysis. The resultant curve obtained from ELEFAN was used as an estimate of deviation from knife-edge recruitment and to compensate for this effect (Pauly and Soriano, 1986).

RESULTS

Twelve species of grunts occur in Puerto Rico, but only three are presently of major importance in the fishery (Table 1). Species composition is based on biostatistical sampling as landings (reported by weight) are not divided by species, but combined under a single category.

White grunt is the primary commercial species with 2979 and 2431 individuals measured in 1984 and 1985 respectively. Annual length frequency for the three major species are showed in Figure 1. Monthly totals ranged from 53 to 511 for white grunt with 17 months over 150 individuals included in the ELEFAN analysis. White grunt bimonthly length frequency distributions are presented in Figure 2. There are several peaks apparent in the data that may be year classes, although it is quite difficult to follow peaks for modal progression analysis or select several peaks for any given month for a NORMSEP-type analysis. The data does seem appropriate for ELEFAN analysis where the numerous peaks will be best fitted to a growth curve. ELEFAN results are reported in Table 2.

Table 1
Haemulon species composition of Puerto Rico commercial catch in 1984-85 based on the CODREMAR biostatistical sampling program (García-Moliner and Kimmel 1985, 1986).

Species	Nº	%	% Cumul.
plumieri	5080	67.2	
flavolineatum	1600	21.2	
sciurus	698	9.2	97.6
macrostomum	63	0.8	
album	39	0.5	
parrai	36	0.5	
aurolineatum	35	0.5	
melanurum	5	< 0.1	
bonariense	1	< 0.1	
TOTAL	7557	100.0	

Stevenson (1976, summarized in Stevenson 1978) measured 279 white grunts in June 1974 and 432 in October 1974. Re-analysis of the data with ELEFAN showed both L_∞ and K were slightly lower for 1973/74 data when compared to 1984/85 data (Table 2).

French grunts were the second most common grunt species in the commercial catch with 1355 individuals measured in 1984, but only 245 in 1985. Only seven months, all in 1984, had more than 90 individuals measured and were used in ELEFAN analysis. Estimates of VBGF parameters and mortality rates are found in Table 2. French grunts grew to the smallest maximum size, reaching that size more rapidly than other species (Fig. 3).

There was limited measurement of bluestriped grunts in 1984 (not used in this analysis) and only 407 individuals measured in 1985. Four months with 50 or more individuals were used in ELEFAN analysis. Bluestriped grunts reached about the same maximum size as white grunts, but reached that size at a slower rate (Fig. 3). VBGF parameters are found in Table 2.

Data are available for comparison of VBGF parameters from Jamaica (Gaut and Munro, 1983; Munro, 1983a) and the earlier analysis of Puerto Rico stocks (Stevenson, 1976) (Table 3). L_∞ was similar among data sets with Puerto Rico fish generally with lower values. One exception was the French grunt that had an L_∞ of about 30% larger than maximum reported size for the species (27 cm FL, Randall, 1968).

The catch curve analysis yielded estimates of total mortality for all three species (Table 2). For the 1985 French grunt dataset the right descending arm of the catch curve was non-linear, thus no total mortality estimate was made by this method.

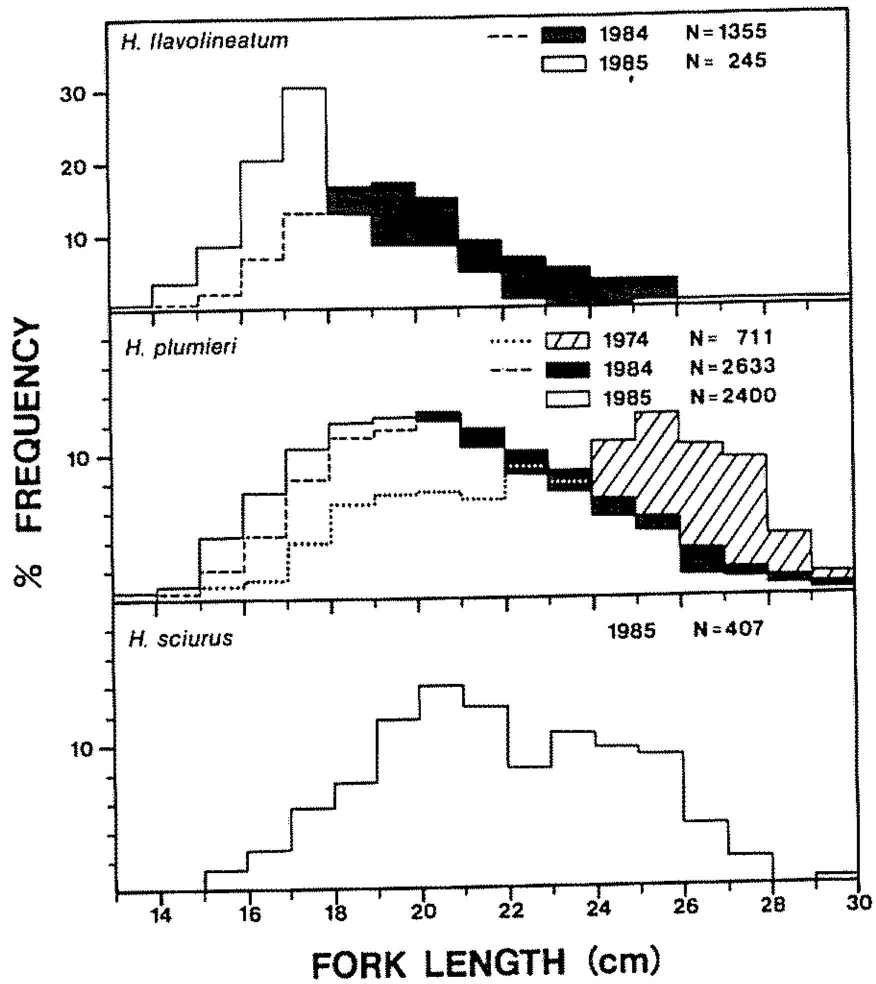

Figure 1
Annual length-frequency distributions for the three dominant grunt species in the Puerto Rico commercial catch

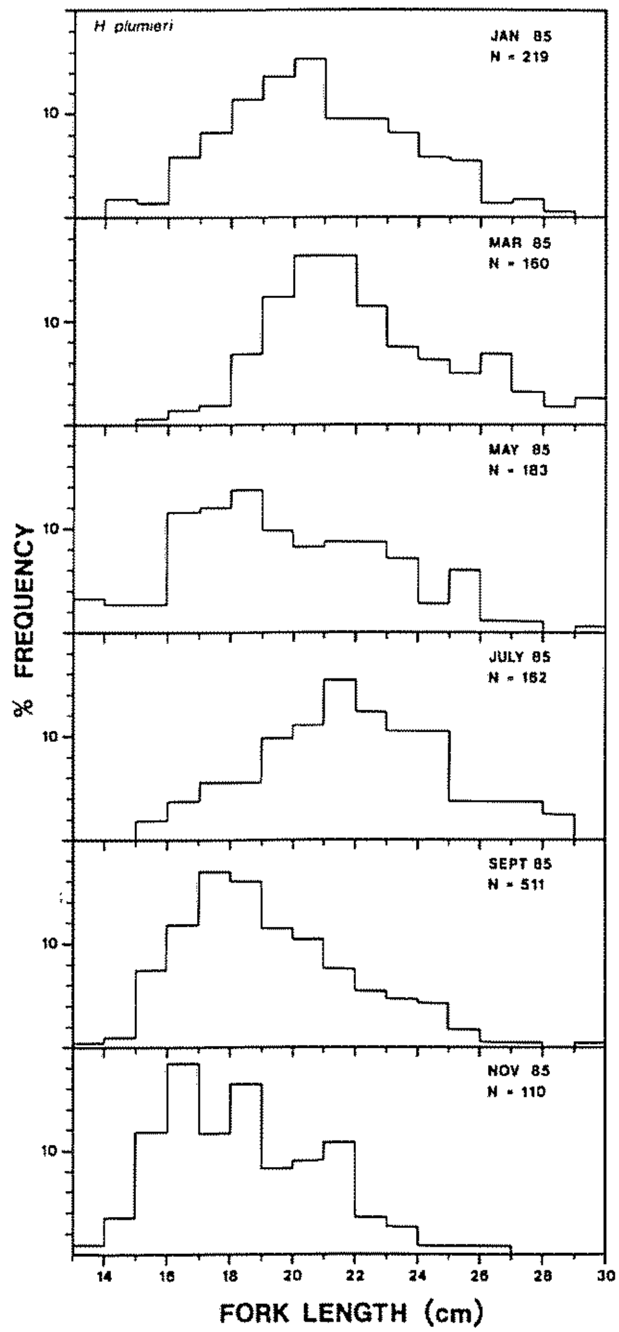

Figure 2
Bimonthly length-frequency distributions for commercially caught white grunt in 1985

Table 2
Von Bertalanffy growth parameters, ELEFAN fit, natural mortality, length at first capture, and total mortality for three species of grunts from Puerto Rico

Species	Yr	L_∞	K	ESP/ ASP	M	l_c	Catch curve Z	B&H Z	Hoening Z
flavolineatum	84	35.0	.24	.527	.66	17.47	1.601	1.186	1.114
	85					*	*	1.694	1.936
plumieri	74	37.0	.31	.601	.77	25.14	2.039	2.028	1.726
	84	37.6	.34	.339	.81	19.16	1.691	1.654	1.530
	85					19.02	1.944	1.885	1.674
sciurus	85	37.1	.30	.679	.75	19.06	1.188	1.453	1.171

* - catch curve non linear.

Table 3
Comparison of VBGF parameters among Caribean stocks of grunts

	Maximum Reported FL	Location	Yr	L_∞	K	Method	Source
flavolineatum	27.0	Jamaica	70/72	25.0	-	3	Gaut & Munro, 1983
		Puerto Rico	84/85	35.0	.24	2	this study
plumieri	40.6	Jamaica	70/72	39.8	.275	1	Gaut & Munro, 1983
		Jamaica	70/72	39.8	.275	2	Munro, 1983
		Puerto Rico	73/74	42.0	.26	1	Steverson, 1976
		Puerto Rico	73/74	37.0	.308	2	this study
		Puerto Rico	84/85	37.6	.34	2	this study
sciurus	40.0	Jamaica	70/72	40.0	.26	1	Gaut & Munro, 1983
		Jamaica	70/72	40.2	.24	2	Munro, 1983
		Puerto Rico	84/85	37.1	.30	2	this study

Method 1 - modal progression 2 - ELEFAN 3 - Estimated based on maximum siz

Table 4

Summary of yield-per-recruit parameters determinig the state of the fishery and optimum levels of fishing

Species	Yr	M/K	C	F	E	Selection corrected $E_{0.1}$	Selection corrected E_{max}	Knife-edge recruitment $E_{0.1}$	Knife-edge recruitment E_{max}
flavolineatum	84	2.75	.50	0.45 - 0.95	0.59 - 0.70	0.61	0.63	0.80	0.94
plumieri	74	2.50	.68	0.96 - 1.27	0.55 - 0.62	0.72	0.72	1.00	1.00
	84	2.38	.51	0.72 - 0.97	0.47 - 0.54	0.57	0.59	0.80	0.87
	85			0.82 - 1.13	0.49 - 0.58	0.56	0.58	0.80	0.87
sciurus	85	2.50	.51	0.44 - 0.70	0.36 - 0.48	0.55	0.62	0.82	0.91

After obtaining an estimate of M from Pauly's (1980) equation, the mean length at first capture (l_c) was estimated for each dataset (Table 2). White grunt natural mortality was slightly lower in 1974, but total mortality was higher than in 1984/85.

From results in Table 2 the yield-per-recruit parameters C and E were calculated (Table 4). The level of effort necessary for optimum yield determined by the $E_{0.1}$ criteria is reported in Table 4.

DISCUSSION

It is important to first determine whether commercial catch data provided reasonable estimates of the VBGF parameters. Most L_∞ estimates appear to be reasonable based on maximum reported size and previous estimates. The much higher L_∞ for French grunts suggests that Puerto Rico has very large French grunts or some identification problems were encountered. The French grunt results should be regarded as tentative until this problem can be resolved.

Of the two VBGF parameters there is greater variability in K (Table 3). In general Puerto Rican results had substantially higher K values. As there is an inverse relationship between K and L_∞ this is compensation in some respects for lower L_∞ values. All the parameter estimates in Table 3 are based on length-frequency data. None of the grunt species in the Caribbean have been absolutely aged to validate these estimates. As such the true accuracy of

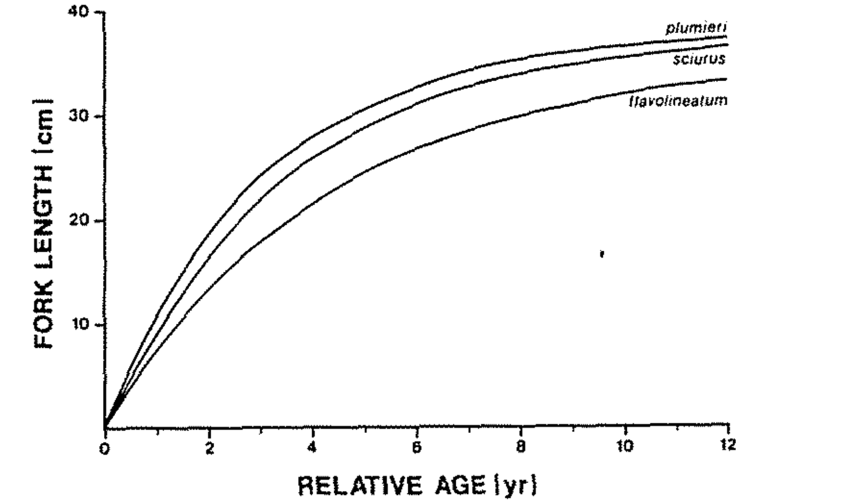

Figure 3
Von Bertalanffy growth curves for the three dominant grunt species in the Puerto Rico commercial catch

the parameters has not been established. Aging studies are pre-sently underway on white grunts at the CODREMAR Fisheries Research Laboratory.

The M/K ratio is the critical parameter in determining yield-per-recruit. This means that the accuracy of estimating M and K has a major impact on the accuracy of the analysis. L_∞ is apparently estimated relatively accurately, but K may be overestimated in the ELEFAN analysis due to the lack of resolution of older age groups (Manooch, 1987; Dennis, in press). This suggests that the true K may be slightly less than predicted here.

There is only a single estimate for M based on Pauly's empirical equation. A comparison between catch curve mortality estimates in relatively unexploited populations and Pauly's equation indicates a tendency to overestimate M by about 45% (Brouard and Grandperrin, 1984; Ralston, 1987). This suggest that major bias in the M/K ratio lies in estimate of M.

The state of the fishery from the initial parameter estimates indicate an exploitation level of at or slightly above optimum for French grunt in 1984 and white grunt for 1985. In 1974 and 1984 white grunt and 1985 bluestriped grunt were exploited below their optimum level (Table 4). The importance of deviation from knife-edge selection is illustrated in the fact that all stocks would be considered underexploited assuming knife-edge selection.

If, as stated above, M is 45% lower than estimated by Pauly's equation and K is roughly the same, the M/K ratio is reduced to 1.31 to 1.51. This change in M/K has only a small effect on optimum yield levels of C and $E_{0.1}$

Table 5
Comparison of selection corrected yield-per-recruit results for the Pauly's natural mortality estimate (M) and 45% lower M (M_{45}).

Species	Yr	M: E	M: $E_{0.1}$	M_{45}: E	M_{45}: $E_{0.1}$
flavolineatum	84	0.59-0.70	0.61	0.75-1.25	0.62
plumieri	74	0.55-0.62	0.72	1.31-1.62	0.66
	84	0.47-0.54	0.57	1.08-1.24	0.56
	85	0.49-0.58	0.56	1.22-1.49	0.56
sciurus	85	0.36-0.48	0.55	0.78-1.04	0.55

but radically changes the assessment of the present state of the fishery (Table 5). A lower M increases both F and E. This indicates substantial overexploitation for all stocks.

Stevenson (1976, 1978) used the yield-per-recruit analysis for 1974 white grunt data and concluded overexploitation was occurring at that time. His analysis differed from the present analysis of his data with ELEFAN in a higher L_∞(42.0 vs 37.0), a lower K (0.26 vs 0.30), and a substantially higher $l_{c'}$ (22.0 vs 26.0) and l_c (18.5 vs 25.1). M was estimated at 1/3 to 2/3 of Z giving a M/K ratio of 1.0 to 2.0 (Stevenson 1976). As Stevenson was manipulating mesh size his optimum yield criteria was C_{opt} for the 1974 exploitation level. This is a MSY criteria thus would be higher than the $E_{\phi.1}$ criteria. His conclusion as to overexploitation is based on selection of substantially lower lc than calculated in this analysis. Based on the present analysis white grunts were substantially underexploited in 1974. This is borne out by the large modal size of the fish in 1974 in comparison to 1984/85 (Fig. 1). Curiously the exploitation rate in 1974 was higher than in 1984/85 even though there has been a tremendous increase in the number of traps. This may be related to the offshore nature of the 1974 data compared to the greater inshore emphasis of the 1984/85 commercial catch. Though the 1984/85 catch was primarily taken on the outer half of the continental shelf. Gaut and Munro (1983) found the same phenomenon in Jamaica where the offshore stocks of *plumieri* at Pedro bank experienced higher mortality than the more heavily exploited inshore stocks. They believed that migration of juvenile grunts from inshore areas to offshore banks caused this discrepancy.

The pattern of white grunt exploitation in the Caribbean can be summarized as follow. In 1970/72 Jamaica's Port Royal reefs (inshore) show to greatest effects of fishing on white grunt with a high Z and a low l_c (Gaut and Munro, 1983). The 1985 Puerto Rico data has a slightly lower Z and higher l_c than the Port Royal reefs. In 1974 Puerto Rico showed a lower exploita-tion rate with a high l_c and low K (discounting the unusually high Z). Pedro bank (1970) shows the lowest exploitation with a high l_c (Gaut and Munro, 1983). By 1981 length-frequency data from Pedro bank show a trend in decreasing size associated with greater exploitation (Hartsuijker, 1982).

The yield-per-recruit parameters C and E are available to managers for manipulation of the fishery to maintain optimum yield. As of September 1986 the CFMC has set a minimum mesh size of 1.25 in (4.24 cm maximum aperture) for fish traps in federal waters (more than 3 nmi from shore). This, in effec, fixes the level of C. Stevenson (1976) found that an increase in mesh size above 1.25 in substantially decreased white grunt catch and would have even greater impact on other commercially important species (e.g. *Epinephelus guttatus* and *Psuedupeneus maculatus*). Also trap selectivity in white grunt is apparently independent of mesh size as the minimum size retained was much larger than theoretically possible based on body depth alone (Gaut and Munro, 1983; Stevenson, 1976). These factors indicate that fishing effort needs to be controlled. The minimum mesh size limit should keep fish size at a reasonable level (ca. C = 0.5). So that if fishing effort (e.g., number of traps) could be limited to the 1984/85 level or slightly lower an optimum yield of grounts could be realized. An expanding fishing effort should lead to lower catch per unit effort and possibly stock recruitment problems. Thus it is recommended that fishing effort in the Puerto Rico trap fishery be limited to the 1984/85 level. Each year a similar type of analysis should be undertaken to determine the state of the fishery and recommend adjustements to management regulations.

There was only good length-frequency data available for analysis of white grunt, which is the most important species in the catch and thus would be most important to regulate. If other species of grunts were thought to contribute significantly to the fishery a larger sample of length-frequency data would be needed to estimate with more confidence the state of the fishery.

If commercial catch length-frequency sampling was to be continued and one objective was a yield-per-recruit analysis then sampling effort might be better spent in obtaining a few large samples rather than the present system of uneven sampling effort spread over the entire year. As there are many species to consider in the commercial catch staggering of sampling effort might allow the collection of adequate sample size over a short time period (e.g., one month). The year could be divided into three four-quarter periods: January, April, July, October; February, May, August, November; and March, June, September, December. Sampling would concentrate on a particular group of target species during each period. Target species would be determined based on dominance in the catch and could be allocated to each period based on historical trends in catch such that a species would be sampled during a period of greatest abundance. This sampling scheme would take into account seasonal differences in recruitment and growth and allow for more efficient use of port agent time. Data gathered from such a system could be used to track the state of the fishery on an annual basis.

ACKNOWLEDGMENTS

I thank G. García-Moliner and J.J. Kimmel of the Commercial Fisheries Laboratory, CODREMAR for sharing their data and knowledge of the Puerto Rican fishery with me. R.S. Appeldoorn is acknowledged for his discussion of the yield per recruit model and giving the author the opportunity to attend these meetings. The help of A. Acosta and F. Grana in providing the Spanish translation of the abstract is gratefully acknowledged. B. Bower-Dennis provided the superb illustrations. Funds for travel and lodging were provided by the University of Puerto Rico Sea Grant Program.

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